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The Network "Quasar": 2008–2011

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Abstract. The paper gives the description of the current status of Russian VLBI Network "Quasar", geometry of the network and its equipment. Modern international and domestic observational programs are described in details. A brief review of upgrade and development of the VLBI Network "Quasar" up to 2011 year is presented.

1. "Quasar" — 2007

In 2005 three radio astronomical observatories of the VLBI Network "Quasar" were put into service (Fig. 1). As a result the three-element VLBI Network with baselines of about $2015 \times 4282 \times 4404$ km connected to the Control and Processing center in St. Petersburg was established (Fig. 1). The Network geometry was chosen to proceed from the requirements of astrometric and geodynamical problems to have equatorial and polar components of baselines and sufficiently large mutual visibility of radio sources with different declinations.

The basic element of the each observatory is a fully steerable 32-meter radio telescope. The antenna was designed on the basis of a modified Cassegrain scheme with a main quasi-parabolic reflector with focal length of about 11.4 meters and the secondary quasi-hyperbolic mirror of 4 meters in diameter. The asymmetric secondary mirror focuses the emission of radio sources aside of the main dish axis and the focal point draws the circle during the rotation of the secondary reflector. It is this circle on which the horns for different wavelengths are located. Fast transfer from one wavelength to another is performed by the rotation of the secondary mirror to a given angle.

The radio telescope drivers allow the antenna to rotate along elevation and azimuth angles with slow and fast rates. There are two types of antenna rotations: low-speed regime for guiding the objects and high-speed regime for antenna changeover with the rates of about of 1.6°/s and of 1.0°/s along elevation and azimuth angles respectively.

The sensitivity of the telescope is provided by a low-noise multi-wave receiving SHF-system which consists of 1.35, 6, 18–21, 3.5, and 13 centimeter double-channels (left and right polarizations) cryogenic radiometers (Tabl. 1),

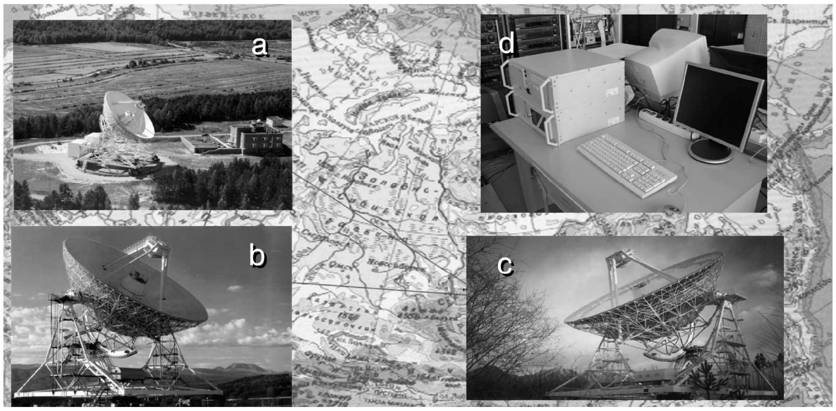

Figure 1. VLBI Network "Quasar" – 2007 (a — Observatory "Svetloe" ($\varphi = 60°32'$, $\lambda = 29°47'$, $h = 86$ m); b — Observatory "Zelenchukskaya" ($\varphi = 43°47'$, $\lambda = 41°34'$, $h = 1175$ m); c — Observatory "Badary" ($\varphi = 51°46'$, $\lambda = 102°$, $h = 813$ m), d — Correlator "MicroParsec" (Saint Petersburg))

Table 1. Parameters of the VLBI Network "Quasar" receivers

Wavelength, cm	Frequency band, GHz	T_r, K	T_{sys}, K	SEFD, Jy
21/18	1.38–1.72	8	43	240
13	2.15–2.50	10	48	330
6	4.60–5.10	8	27	140
3.5	8.18–9.08	11	34	200
1.35	22.02–22.52	20	80	710

the last two being used for joint reception in S/X range.

The time-keeping complex of each observatory is the unified system, which consists of a hydrogen maser with 3×10^{-15} stability for 1000 s time of averaging, site clock, and the GPS/GLONASS timing receivers for time synchronization with about 50 nanosecond accuracy. The synchronized SHF-local oscillators with 1.26, 2.02, 4.5, 8.08, 22.92 GHz as well as picoseconds impulses generator are included into the system.

The system of transforming, formatting, and receiving signal for radiometric and VLBI modes operates in the 100–1000 MHz basic range of intermediate frequencies. It permits to use the system with radio astronomical receivers of any type. The system consists of two main sub-systems of radiometric and VLBI units connected to the outputs of receivers by wideband coaxial link.

A radiometric unit allows to carry out radiometric observations in two frequency channels and two polarizations simultaneously [1]. This system is used for the Sun, galactic, and extragalactic radio sources observational programs [2–9].

Mark IV, VLBA4 and P1000 (developed by IAA [10]) data acquisition systems and the S2, Mark 4, Mark 5A, Mark 5B recording terminals are used for operation in VLBI-mode. This system is used for VLBI observations carried out according to both international and domestic astrometrical, geodynamical, and geodetic programs [11–16].

The observations, planning, testing and express analysis are accomplished by automatic control of facilities mentioned above. The program packages NASA SKED and NRAO SCHED are used for planning astrometrical and astrophysical VLBI programs, respectively. The program package IAA Sched Maker [17] is used for radiometric observations planning. The program systems NOVAS-C (USNO) and ERA (IAA) [18] are used for obtaining ephemeredes of Solar system bodies. Using these packages the control files are prepared and transmitted to main frame computer of each observatory where Mark IV Field System (FS) is installed. The special software is included in Mark IV FS for the control of radio telescope, time-keeping system, and DAS P1000.

There are two domestic programs: Ru-E — daily observations on the 3-baselines interferometer for determining all Earth orientation parameters, and Ru-U —observations of 8-hour duration for obtaining Universal Time. The 2-station correlator "MicroParsec" processes the VLBI observational data in S2 format transmitted from each station through the digital communication channels at 128 Mbps rate [19].

A brief review of upgrade and development of the VLBI Network "Quasar" up to 2011 year will be presented below.

2. "Quasar" — 2008–2009

In 2008 the VLBI Network "Quasar" will be upgraded to permit reliable 24-hours everyday operation. Fig. 2 shows the main features of the observatories hardware upgrade which has to be completed by the end of 2008. The main components of this upgrade are the following:

- Substitution of gear and pointing systems electronic (USUK "Salgir" is to be replaced by the USUK "Salgir-M") which allows to cut down the rack size, simplify power supply parameters (from 220 V and 400 Hz to 36 V and 50 Hz) and for increasing the system reliability.
- Upgrade of the frequency transformation block for receivers of S/X range on the basis of new generation chips, which improve amplitude-frequency characteristics and expanded dynamical range significantly.
- Replacement of the CH1-80 hydrogen maser by CH1-80 and CH1-75 ones to increase reliability characteristics and permits their remote control through the communication lines and Internet. It should be noted that the new generation hydrogen masers CH1-75 have higher stability (better then 10^{-15} for 24 hours) as compared with CH1-80 masers.
- Replacement of data acquisition systems DAS Mark 4, DAS VLBA4, and DAS P1000 to a digital DAS P1002 which consists of 16 absolutely

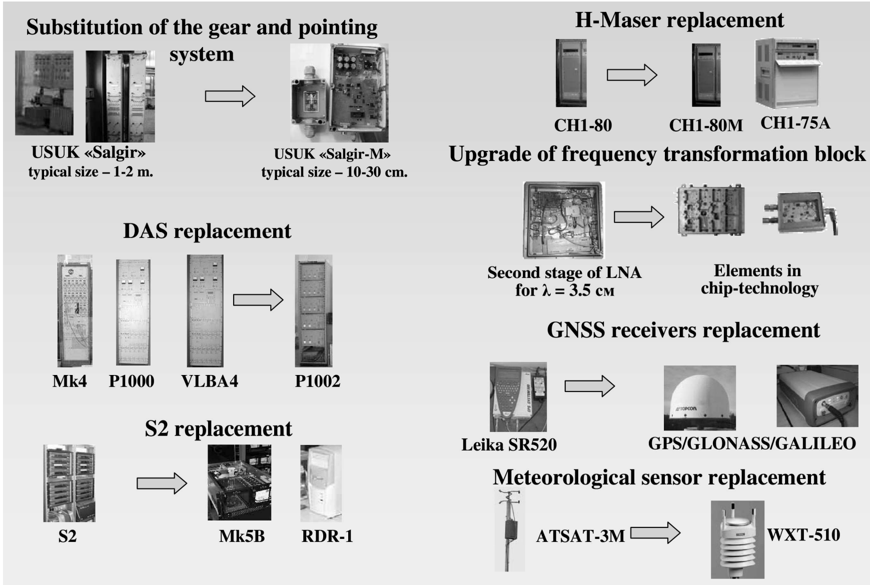

Figure 2. Upgrade and development of VLBI Network "Quasar"

identical frequency channels with high quality digital filters. This data acquisition system will be fully compatible with modern analog systems and makes it possible to over program the frequency bandwidths and keep phase-and-frequency channel characteristics.

- Replacement of S2 tape recorders to disk terminals Mark 5B and RDR-1 [20] recording signals in VSI-H and S2 modes correspondingly. Installation of the Mark 5B terminal makes it possible not only to record data flows on disks, but also to attach this device to the equipment required for e–VLBI mode of data transmission. The RDR-1 terminals will be used since 2009 in observation within the RADIOASTRON space mission.
- Replacement of geodetic GPS-receivers to three-system GPS/GLONASS/ GALILEO receivers and Russian meteo-station ATSAT-3M to the more modern WXT-510.

In 2007 all observatories of the VLBI Network "Quasar" were linked by optical fiber lines (Fig. 3) to provide both e–VLBI mode for determining the Universal Time in intensive 1-hour sessions and real-time remote monitoring of each part of the Network. At present the observatories have data transmission channels to St. Petersburg at 2 Mbps rate. By the end of 2008 the observatories and the Control and Processing Center of the Network "Quasar" will be supplied by hardware and software providing VLBI data transmission rates of at least 100 Mbps.

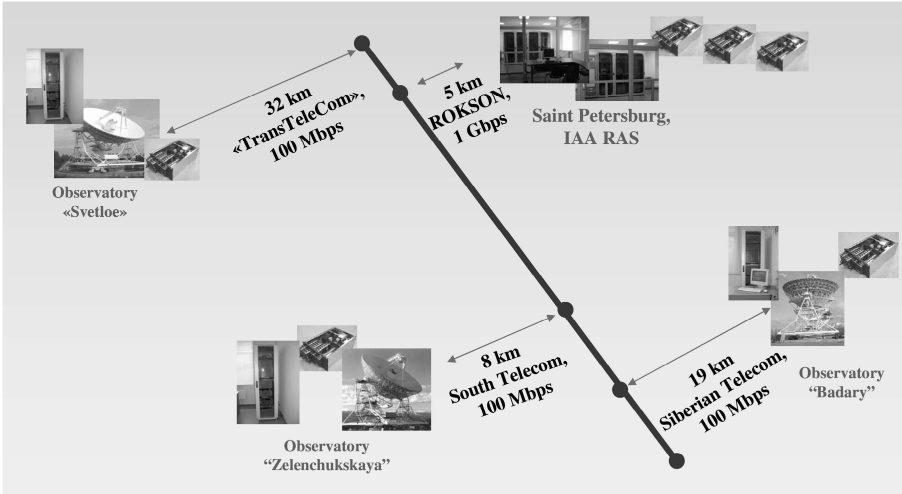

Figure 3. Optical Fiber Lines of VLBI Network "Quasar"

In 2008, IVS VLBI programs make use of Mark 5A and Mark 5B recording terminals. The domestic programs Ru-E and Ru-U are being carried out twice per month with S2 and Mark 5B terminals.

3. "Quasar" — 2009–2010

In 2009 the 6-station correlator ARC [21] will be put into action. It will provide processing data for 16 channels with 16 MHz bandwidth and two-byte sampling for each of 15 baselines. It will be used for processing once per week data of domestic Ru-E and Ru-U with Mark 5B terminals as well as data of IVS programs with Mark 5A and Mark 5B terminals.

At the same time Russian satellite laser ranging system "Sazhen-TM" will be mounted at the observatory "Svetloe" (Fig. 4). It makes possible to range satellites at 400–23000 km height. In 2010 the "Zelenchukskaya" and "Badary" observatories will be supplied by the same facilities. Co-location of VLBI with SLR and GPS/GLONASS/GALILEO facilities will decrease random and, what is the most important, systematic errors of determining Earth orientation parameters and dynamical celestial and terrestrial frames.

In 2010 two main problems will be solved:

- Mounting VLBI equipment on radio telescope RT-70 (Ussurijsk, Far East) with 70-meter dish and unification RT-70 (Fig. 5) with the Network "Quasar" for participation in astrometrical, geodetic, and deep space programs.
- Starting every day intensive sessions for UT-determination in e–VLBI mode.

Satellite heights	400–23000 km
Optical system diameter	25 cm
Laser pulse frequency	300 Hz
Pulse energy	2.5 mJ
Mass	120 kg
Normal points precision	1 cm
Angular precision	1–2”

Figure 4. Satellite Laser Ranging System “Sazhen-TM”

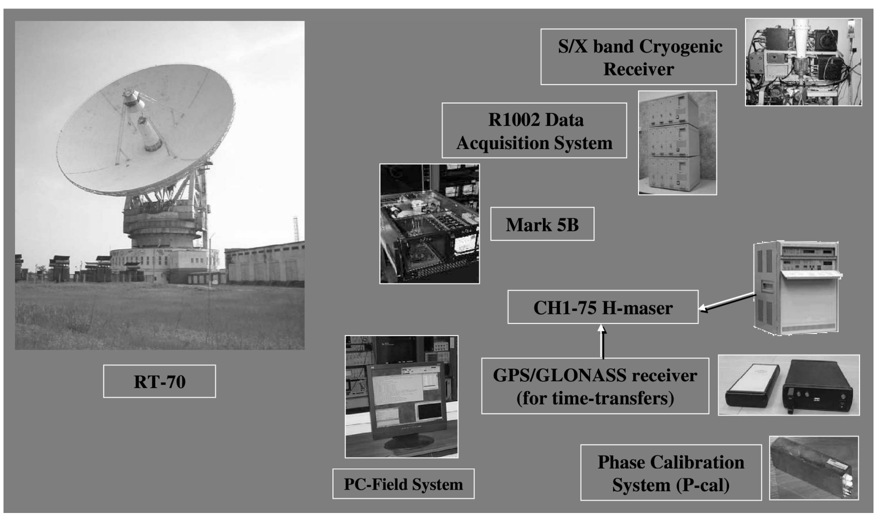

Figure 5. Upgrade of Radio Telescope RT-70 (Ussurijsk, Far East)

4. "Quasar" — 2011

Fig. 6 demonstrates the structure of the VLBI Network "Quasar" at the beginning of 2011.

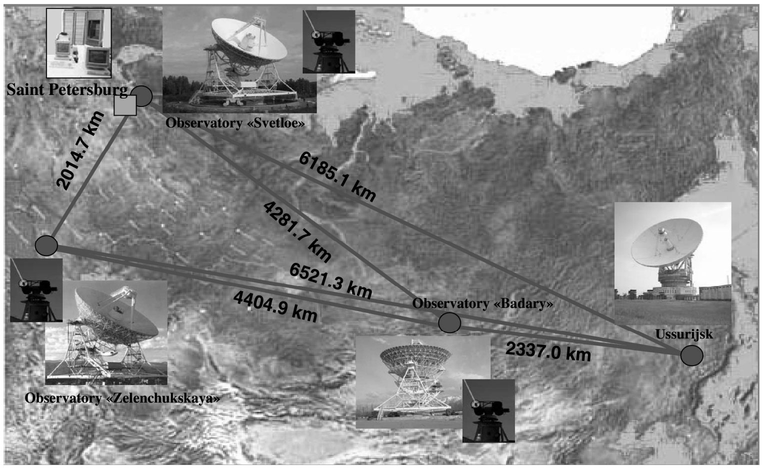

Figure 6. The VLBI Network "Quasar" — 2011

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